Because research and development chemists are increasingly expected to work on interdisciplinary teams, some understanding of other disciplines, including business and marketing or economics, is desirable, along with leadership ability and good oral and written communication skills. Experience, either in academic laboratories or through internships or co-op programs in industry, also is useful. Some employers of research chemists, particularly in the pharmaceutical industry, prefer to hire individuals with several years of postdoctoral experience.

Graduate students typically specialize in a subfield of chemistry, such as analytical chemistry or polymer chemistry, depending on their interests and the kind of work they wish to do. For example, those interested in doing drug research in the pharmaceutical industry usually develop a strong background in synthetic organic chemistry. However, students normally need not specialize at the undergraduate level. In fact, undergraduates who are broadly trained have more flexibility when job hunting or changing jobs than if they narrowly define their interests. Most employers provide new graduates additional training or education.

In government or industry, beginning chemists with a bachelor's degree work in quality control, analytical testing, or assist senior chemists in research and development laboratories. Many employers prefer chemists with a Ph.D. or at least a master's degree to lead basic and applied research. A Ph.D. is also often preferred for advancement to many administrative positions.

Job Outlook

Employment of chemists is expected to grow about as fast as the average for all occupations through 2008. Job growth will be concentrated in drug manufacturing and research, development, and testing services firms. The chemical industry, the major employer of chemists, should face continued demand for goods such as new and better pharmaceuticals and personal care products, as well as more specialty chemicals designed to address specific problems or applications. To meet these demands, chemical firms will continue to devote money to research and development—through in-house teams or outside contractors—spurring employment growth of chemists.

Within the chemical industry, job opportunities are expected to be most plentiful in pharmaceutical and biotechnology firms. Stronger competition among drug companies and an aging population are contributing to the need for innovative and improved drugs discovered through scientific research. Chemical firms that develop and manufacture personal products such as toiletries and cosmetics must continually innovate and develop new and better products to remain competitive. Additionally, as the population grows and becomes better informed, the demand for different or improved grooming products—including vegetable-based products, products with milder formulas, treatments for aging skin, and products that have been developed using more benign chemical processes than in the past—will remain strong, spurring the need for chemists.

In most of the remaining segments of the chemical industry, employment growth is expected to decline as companies downsize and turn to outside contractors to provide specialized services. Nevertheless, some job openings will result from the need to replace chemists who retire or otherwise leave the labor force. Quality control will continue to be an important issue in the chemical and other industries that use chemicals in their manufacturing processes. Chemists will also be needed to develop and improve the technologies and processes used to produce chemicals for all purposes, and to monitor and measure air and water pollutants to ensure compliance with local, State, and Federal environmental regulations.

Outside the chemical industry, firms that provide research, development, and testing services are expected to be the source of numerous job opportunities between 1998 and 2008. Chemical companies, including drug manufacturers, are increasingly turning to these services to perform specialized research and other work formerly done by in-house chemists. Chemists will also be needed to work in research and testing firms that focus on environmental testing and cleanup.

During periods of economic recession, layoffs of chemists may occur—especially in the industrial chemicals industry. This industry provides many of the raw materials to the auto manufacturing and construction industries, both of which are vulnerable to temporary slowdowns during recessions.

Earnings

Median annual earnings of chemists in 1998 were $46,220. The middle 50 percent earned between $34,580 and $68,360. The lowest 10 percent earned less than $27,240 and the highest 10 percent earned more than $86,260. Median annual earnings in the industries employing the largest numbers of chemists in 1997 were:

Federal Government	$62,800
Drugs	43,300
Research and testing services	34,500

A survey by the American Chemical Society reports that the median salary of all their members with a bachelor's degree was $50,100 a year in 1999; with a master's degree, $61,000; and with a Ph.D., $76,000. Median salaries were highest for those working in private industry; those in academia earned the least. According to an ACS survey of recent graduates, inexperienced chemistry graduates with a bachelor's degree earned a median starting salary of $29,500 in 1998; with a master's degree, $38,500; and with a Ph.D., $59,300. Among bachelor's degree graduates, those who had completed internships or had other work experience while in school commanded the highest starting salaries.

In 1999, chemists in nonsupervisory, supervisory, and managerial positions in the Federal Government earned an average salary of $64,200.

Related Occupations

The work of chemical engineers, agricultural scientists, biological scientists, and chemical technicians is closely related to the work done by chemists. The work of other physical and life science occupations, such as physicists and medical scientists, may also be similar to that of chemists.

Sources of Additional Information

General information on career opportunities and earnings for chemists is available from:

☛ American Chemical Society, Education Division, 1155 16th St. NW., Washington, DC 20036. Internet: **http://www.acs.org**

Information on acquiring a job as a chemist with the Federal Government may be obtained from the Office of Personnel Management through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (912) 757-3000; TDD (912) 744-2299. That number is not toll free and charges may result. Information also is available from their Internet site: **http://www.usajobs.opm.gov**

Geologists, Geophysicists, and Oceanographers

(O*NET 24111A and 24111B)

Significant Points

- Work at remote field sites is common.
- A bachelor's degree in geology or geophysics is adequate for entry-level jobs; better jobs with good advancement potential usually require at least a master's degree. A Ph.D. degree is required for most research positions in colleges and universities and in government.

Nature of the Work

Geologists, geophysicists, and oceanographers use their knowledge of the physical makeup and history of the Earth to locate water, mineral, and energy resources; protect the environment; predict future geologic hazards; and offer advice on construction and land use projects. By using sophisticated instruments and analyses of the Earth and water, geological scientists, also known as *geoscientists*, study the Earth's geologic past and present in order to make predictions about its future. For example, they may study the Earth's movements to try to predict when and where the next earthquake or volcano will occur and the probable impact on surrounding areas to minimize the damage.

Geology, geophysics, and oceanography are closely related fields; but there are major differences. *Geologists* study the composition, processes, and history of the Earth. They try to find out how rocks were formed and what has happened to them since formation. They also study the evolution of life by analyzing plant and animal fossils. *Geophysicists* use the principles of physics, mathematics, and chemistry to study not only the Earth's surface, but also its internal composition; ground and surface waters; atmosphere; oceans; and its magnetic, electrical, and gravitational forces. *Oceanographers* use their knowledge of geology and geophysics, in addition to biology and chemistry, to study the world's oceans and coastal waters. They study the motion and circulation of the ocean waters and their physical and chemical properties, and how these properties affect coastal areas, climate, and weather.

Many geologists, geophysicists and oceanographers are involved in the search for oil and gas, but other geological scientists play an important role in preserving and cleaning up the environment. Activities include designing and monitoring waste disposal sites, preserving water supplies, and reclaiming contaminated land and water to comply with Federal environmental regulations.

Geoscientists can spend a large part of their time in the field identifying and examining rocks, studying information collected by remote sensing instruments in satellites, conducting geological surveys, constructing field maps, and using instruments to measure the Earth's gravity and magnetic field. For example, they often perform seismic studies, which involve bouncing energy waves off buried rock layers, to search for oil and gas or understand the structure of subsurface rock layers. Seismic signals generated by earthquakes are used to determine the earthquake's location and intensity.

In laboratories, geologists and geophysicists examine the chemical and physical properties of specimens. They study fossil remains of animal and plant life or experiment with the flow of water and oil through rocks. Some geoscientists use two- or three-dimensional computer modeling to portray water layers and the flow of water or other fluids through rock cracks and porous materials. They use a variety of sophisticated laboratory instruments, including x-ray diffractometers, which determine the crystal structure of minerals, and petrographic microscopes, for the study of rock and sediment samples.

Geoscientists working in mining or the oil and gas industry sometimes process and interpret data produced by remote sensing satellites to help identify potential new mineral, oil, or gas deposits. Seismic technology is also an important exploration tool. Seismic waves are used to develop a three-dimensional picture of underground or underwater rock formations. Seismic reflection technology may also reveal unusual underground features that sometimes indicate accumulations of natural gas or petroleum, facilitating exploration and reducing the risks associated with drilling in previously unexplored areas.

Numerous subdisciplines or specialties fall under the two major disciplines of geology and geophysics that further differentiate the type of work geoscientists do. For example, *petroleum geologists* explore for oil and gas deposits by studying and mapping the subsurface of the ocean or land. They use sophisticated geophysical instrumentation, well log data, and computers to interpret geological information. *Engineering geologists* apply geologic principles to the fields of civil and environmental engineering, offering advice on major construction projects and assisting in environmental remediation and natural hazard reduction projects. *Mineralogists* analyze and classify minerals and precious stones according to composition and structure and study their environment in order to find new mineral resources. *Paleontologists* study fossils found in geological formations to trace the evolution of plant and animal life and the geologic history of the Earth. *Stratigraphers* study the formation and layering of rocks to understand the environment in which they were formed. *Volcanologists* investigate volcanoes and volcanic phenomena to try to predict the potential for future eruptions and possible hazards to human health and welfare.

Geophysicists may specialize in areas such as geodesy, seismology, or magnetic geophysics. *Geodesists* study the size and shape of the Earth, its gravitational field, tides, polar motion, and rotation. *Seismologists* interpret data from seismographs and other geophysical instruments to detect earthquakes and locate earthquake-related faults. *Geochemists* study the nature and distribution of chemical elements in ground water and Earth materials. *Geomagnetists* measure the Earth's magnetic field and use measurements taken over the past few centuries to devise theoretical models to explain the Earth's origin. *Paleomagnetists* interpret fossil magnetization in rocks and sediments from the continents and oceans, to record the spreading of the sea floor, the wandering of the continents, and the many reversals of polarity that the Earth's magnetic field has undergone through time. Other geophysicists study atmospheric sciences and space physics. (See the statements

Geoscientists use a variety of sophisticated equipment.

on atmospheric scientists and physicists and astronomers elsewhere in the *Handbook*.)

Hydrology is closely related to the disciplines of geology and geophysics. *Hydrologists* study the quantity, distribution, circulation, and physical properties of underground and surface waters. They study the form and intensity of precipitation, its rate of infiltration into the soil, its movement through the Earth, and its return to the ocean and atmosphere. The work they do is particularly important in environmental preservation, remediation, and flood control.

Oceanography also has several subdisciplines. *Physical oceanographers* study the ocean tides, waves, currents, temperatures, density, and salinity. They study the interaction of various forms of energy, such as light, radar, sound, heat, and wind with the sea, in addition to investigating the relationship between the sea, weather, and climate. Their studies provide the Maritime Fleet with up-to-date oceanic conditions. *Chemical oceanographers* study the distribution of chemical compounds and chemical interactions that occur in the ocean and sea floor. They may investigate how pollution affects the chemistry of the ocean. *Geological and geophysical oceanographers* study the topographic features and the physical makeup of the ocean floor. Their knowledge can help oil and gas producers find these minerals on the bottom of the ocean. *Biological oceanographers*, often called marine biologists, study the distribution and migration patterns of the many diverse forms of sea life in the ocean. (See the statement on biological and medical scientists elsewhere in the *Handbook*.)

Working Conditions

Some geoscientists spend the majority of their time in an office, but many others divide their time between fieldwork and office or laboratory work. Geologists often travel to remote field sites by helicopter or four-wheel drive vehicles and cover large areas on foot. An increasing number of exploration geologists and geophysicists work in foreign countries, sometimes in remote areas and under difficult conditions. Oceanographers may spend considerable time at sea on academic research ships. Fieldwork often requires working long hours, but workers are usually rewarded by longer than normal vacations. Geoscientists in research positions with the Federal Government or in colleges and universities often are required to design programs and write grant proposals in order to continue their data collection and research. Geoscientists in consulting jobs face similar pressures to market their skills and write proposals to maintain steady work. Travel is often required to meet with prospective clients or investors.

Employment

Geologists, geophysicists, and oceanographers held about 44,000 jobs in 1998. Many more individuals held geology, geophysics, and oceanography faculty positions in colleges and universities, but they are considered college and university faculty. (See the statement on college and university faculty elsewhere in the *Handbook*.)

Among salaried geologists and geophysicists, nearly 1 in 3 were employed in engineering and management services, and 1 in 6 worked for oil and gas extraction companies or metal mining companies. About 1 geoscientist in 8 was self-employed; most were consultants to industry or government.

The Federal Government employed about 5,800 geologists, geophysicists, oceanographers, and hydrologists in 1998. Over half worked for the Department of the Interior, mostly within the U.S. Geological Survey (USGS). Others worked for the Departments of Defense, Agriculture, Commerce, and Energy, and the Environmental Protection Agency. Over 3,000 worked for State agencies, such as State geological surveys and State departments of conservation.

Training, Other Qualifications, and Advancement

A bachelor's degree in geology or geophysics is adequate for some entry-level jobs, but more job opportunities and better jobs with good advancement potential usually require at least a master's degree in geology or geophysics. Persons with degrees in physics, chemistry, mathematics, or computer science may also qualify for some geophysics or geology jobs, if their coursework included study in geology. A Ph.D. degree is required for most research positions in colleges and universities, Federal agencies, and State geological surveys.

Hundreds of colleges and universities offer a bachelor's degree in geology; fewer schools offer programs in geophysics, oceanography, or other geosciences. Other programs offering related training for beginning geological scientists include geophysical technology, geophysical engineering, geophysical prospecting, engineering geology, petroleum geology, hydrology, and geochemistry. In addition, several hundred universities award advanced degrees in geology or geophysics.

Traditional geoscience courses emphasizing classical geologic methods and topics (such as mineralogy, paleontology, stratigraphy, and structural geology) are important for all geoscientists. Those students interested in working in the environmental or regulatory fields, either in environmental consulting firms or for Federal or State governments, should take courses in hydrology, hazardous waste management, environmental legislation, chemistry, fluid mechanics, and geologic logging. An understanding of environmental regulations and government permit issues is also valuable for those planning to work in mining and oil and gas extraction. Computer skills are essential for prospective geoscientists; students who have some experience with computer modeling, data analysis and integration, digital mapping, remote sensing, and geographic information systems (GIS) will be the most prepared entering the job market. A knowledge of the Global Positioning System (GPS)—a locator system that uses satellites—is also very helpful. Some employers seek applicants with field experience, so a summer internship may be beneficial to prospective geoscientists.

Geologists, geophysicists, and oceanographers must have good interpersonal skills, because they usually work as part of a team with other scientists, engineers, and technicians. Strong oral and written communication skills are also important, because writing technical reports and research proposals, as well as communicating research results to others, are important aspects of the work. Because many jobs require foreign travel, knowledge of a second language is becoming an important attribute to employers. Geoscientists must be inquisitive and able to think logically and have an open mind. Those involved in fieldwork must have physical stamina.

Geologists and geophysicists often begin their careers in field exploration or as research assistants or technicians in laboratories or offices. They are given more difficult assignments as they gain experience. Eventually, they may be promoted to project leader, program manager, or another management and research position.

Job Outlook

Employment of geologists, geophysicists, and oceanographers is expected to grow about as fast as the average through 2008. The need to replace geologists, geophysicists, and oceanographers who retire will result in many additional job openings over the next decade. Driving the growth will be the need for organizations to comply with an increasing number of environmental laws and regulations, particularly those regarding groundwater contamination and flood control. Increased construction and exploration for oil and natural gas abroad will require geoscientists to work overseas. In the short-run, however, low energy prices, oil company mergers, and stagnant or declining government funding for research may affect the hiring of petroleum geologists and geoscientists involved in research.

In the past, employment of geologists and some other geoscientists has been cyclical and largely affected by the price of oil and gas.

When prices were low, oil and gas producers curtailed exploration activities and laid off geologists. When prices were up, companies had the funds and incentive to renew exploration efforts and hire geoscientists in large numbers. In recent years, a growing worldwide demand for oil and gas and new exploration and recovery techniques—particularly in deep water and previously inaccessible sites—have returned some stability to the petroleum industry, with a few companies increasing their hiring of geoscientists. Growth in this area, though, will be limited due to increasing efficiencies in finding oil and gas. Geoscientists who speak a foreign language and who are willing to work abroad should enjoy the best opportunities.

In the environmental field, the need for companies to comply with an increasing number of laws and regulations will contribute to the demand for geoscientists, especially hydrologists and engineering geologists. As the population increases and moves to more environmentally sensitive locations, geoscientists will be needed to assess building sites for potential geologic hazards and to address issues of pollution control and waste disposal. An expected increase in highway building and other infrastructure projects will be an additional source of jobs for engineering geologists.

Jobs with the Federal and State governments and with organizations dependent on Federal funds for support will experience little growth over the next decade, unless budgets increase significantly. This lack of funding will affect mostly oceanographers and those geoscientists performing basic research.

Earnings

Median annual earnings of geologists, geophysicists, and oceanographers were $53,890 in 1998. The middle 50 percent earned between $39,830 and $79,630 a year. The lowest 10 percent earned less than $30,950 and the highest 10 percent earned more than $101,390. Median annual earnings in the industries employing the largest number of geoscientists in 1997 were as follows.

Crude petroleum and natural gas	$81,900
Management and public relations	44,900
Engineering and architectural services	44,700

According to the National Association of Colleges and Employers, beginning salary offers in 1999 for graduates with bachelor's degrees in geology and the geological sciences averaged about $34,900 a year; graduates with a master's degree averaged $44,700.

In 1999, the Federal Government's average salary for geologists in managerial, supervisory, and nonsupervisory positions was $64,400; for geophysicists, $72,500; for hydrologists, $58,900; and for oceanographers, $66,000.

The petroleum, mineral, and mining industries offer higher salaries, but less job security, than other industries. These industries are vulnerable to recessions and changes in oil and gas prices, among other factors, and usually release workers when exploration and drilling slow down.

Related Occupations

Many geologists and geophysicists work in the petroleum and natural gas industry. This industry also employs many other workers in the scientific and technical aspects of petroleum and natural gas exploration and extraction, including engineering technicians, science technicians, petroleum engineers, and surveyors. Also, some life scientists, physicists, chemists, and atmospheric scientists—as well as mathematicians, computer scientists, soil scientists, and cartographers—perform related work in both petroleum and natural gas exploration and extraction and in environment-related activities.

Sources of Additional Information

Information on training and career opportunities for geologists is available from:

☛ American Geological Institute, 4220 King St., Alexandria, VA 22302-1502. Internet: **http://www.agiweb.org**

☛ Geological Society of America, P.O. Box 9140, Boulder, CO 80301-9140. Internet: **http://www.geosociety.org**

☛ American Association of Petroleum Geologists, P.O. Box 979, Tulsa, OK 74101. **Internet: http://www.aapg.org**

Information on training and career opportunities for geophysicists is available from:

☛ American Geophysical Union, 2000 Florida Ave. NW., Washington, DC 20009. Internet**: http://www.agu.org**

☛ Society of Exploration Geophysicists, 8801 South Yale, Tulsa, OK 74137. Internet: **http://www.seg.org**

A list of education and training programs in oceanography and related fields is available from:

☛ Marine Technology Society, 1828 L St. NW, Suite 906, Washington, DC 20036. Internet: **http://www.mtsociety.org**

Information on acquiring a job as a geologist, geophysicist, hydrologist, or oceanographer with the Federal Government may be obtained through a telephone-based system from the Office of Personnel Management. Consult your telephone directory under U.S. Government for a local number, or call (912) 757-3000 (TDD 912 744-2299). This number is not toll-free, and charges may result. Information also is available from the Internet site: **http://www.usajobs.opm.gov**

Physicists and Astronomers

(O*NET 24102A and 24102B)

Significant Points

- A doctoral degree is the usual educational requirement because most jobs are in basic research and development; a bachelor's or master's degree is sufficient for some jobs in applied research and development.
- As funding for research grows slowly or not at all, new Ph.D. graduates will face competition for basic research jobs.

Nature of the Work

Physicists explore and identify basic principles governing the structure and behavior of matter, the generation and transfer of energy, and the interaction of matter and energy. Some physicists use these principles in theoretical areas, such as the nature of time and the origin of the universe; others apply their physics knowledge to practical areas, such as the development of advanced materials, electronic and optical devices, and medical equipment.

Physicists design and perform experiments with lasers, cyclotrons, telescopes, mass spectrometers, and other equipment. Based on observations and analysis, they attempt to discover and explain laws describing the forces of nature, such as gravity, electromagnetism, and nuclear interactions. Physicists also find ways to apply physical laws and theories to problems in nuclear energy, electronics, optics, materials, communications, aerospace technology, navigation equipment, and medical instrumentation.

Astronomy is sometimes considered a subfield of physics. *Astronomers* use the principles of physics and mathematics to learn about the fundamental nature of the universe, including the sun, moon, planets, stars, and galaxies. They also apply their knowledge to solve problems in navigation, space flight, and satellite communications and to develop the instrumentation and techniques used to observe and collect astronomical data.

Most physicists work in research and development. Some do basic research to increase scientific knowledge. Physicists who conduct applied research build upon the discoveries made through basic research and work to develop new devices, products, and processes. For instance, basic research in solid-state physics led to the development of transistors and then to the integrated circuits used in computers.